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Marine Biological Features in the Equatorial Current Region at 164°E*

Hachiro HIRATA,** Toshio SAISHO*** and Masaaki CHAEN****

Abstract

The Equatorial Current Region at 164°E was investigated from the view points of oceanography and marine biology. Distributions of suspended particles and zooplankton in the region were presented. Characteristics of the distributions were related to the existence of the Equatorial Currents such as the South Equatorial Current, the Equatorial Countercurrent and the North Equatorial Current. On the other hand, in order to know the boundary of water masses, continuous record of D. O. contents in the surface water was tried in advance, and conducted for the detection of small current rips.

1. Introduction

Since 1974, a project of marine ecological survey in the western Equatorial Pacific and adjacent seas has been set up to study skipjack fishing biology by the teamwork beyond the laboratories in the Faculty of Fisheries, Kagoshima University. The first survey was made in the Banda Sea, Indonesia, in 1974, and the results related on a Coulter Counter analysis were reported preliminarily by HIRATA, KADOWAKI, SAKASHITA, WENNO, UKTLSEJA and RAWUNG (1975). Then, the second survey was carried out along the meridian of 164°E from the equator to 12°N in 1975. A summary of the second survey entitled as Prompt Report '76 was published already (CHAEN, UEDA, HIGASHIKAWA, NISHI, ARIMA and MASUMITSU; 1976, HIRATA, YAMAGUCHI, HIGASHIKAWA, KOHIRATA and WENNO; 1976, SAISHO; 1976).

The materials presented in this paper were rearranged from the results reported on the Prompt Report '76, and analyzed cooperatively from the view points of oceanography and marine biology. Some ecological features such as distributions of suspended particles and zooplankton in the waters were discussed concerning with the existence of three major currents in the region. On the other hand, in order to know the boundary of water masses, continuous record of D. O. contents in the surface

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** Laboratory of Fish Cultivation Physiology, Faculty of Fisheries, Kagoshima University, Kagoshima City, 890 Japan.

*** Laboratory of Marine Biology, Faculty of Fisheries, Kagoshima University, Kagoshima City, 890 Japan.

**** Laboratory of Oceanography, Faculty of Fisheries, Kagoshima University, Kagoshima City, 890 Japan.

water was tried in advance, and conducted for the detection of small current rips. It is hoped that the materials and trials would serve as a useful reference for future studies concerned with the fishing ground of skipjack.

2. Observations

2–1. Water Masses

An oceanographic section in the second survey was carried out on board the Kagoshima Maru of the Kagoshima University along the meridian of 164°E from the equator to 12°N at an interval of every 90 miles as shown in Fig. 1 from November 29 to December 5, 1975. Vertical distributions of water temperature, salinity, D. O., pH and geopotential anomaly were presented in the Prompt Report '76 by Chaen, Ueda, Higashikawa, Nishi, Arima and Masumitsu (1976).

Based on the vertical distributions of geopotential anomaly refered to 1,000 db surface and water temperature, the Equatorial Current through the section may be divided into three major zones: the South Equatorial Current south of 4°30′N; the Equatorial Countercurrent between 4°30′N and 7°30′N; the North Equatorial Current north of 7°30′N. However, the current boundaries could not be delimited because the interval between two oceanographic stations was 90 miles apart. The

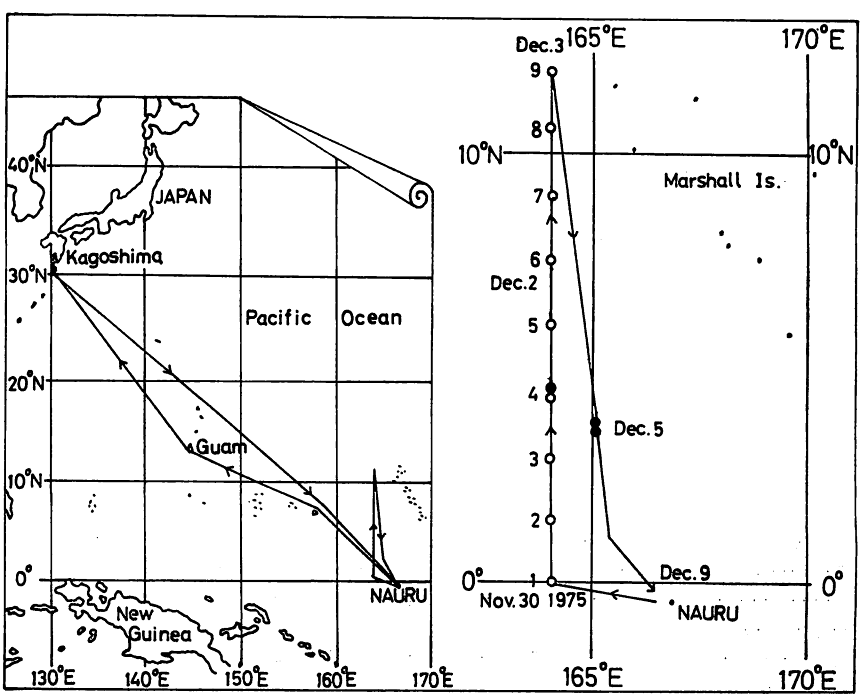

Fig. 1. Map showing the track and oceanographic stations. The open circle and black circle indicate the Nansen cast station down to 1000 m depth and 400 m depth, respectively.

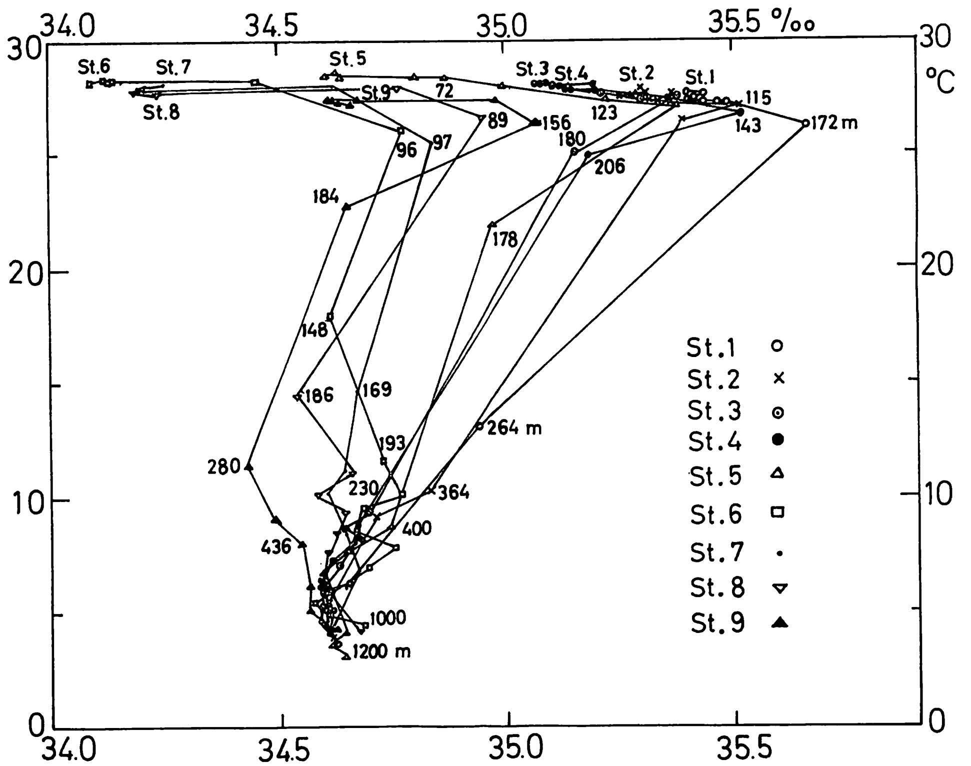

Fig. 2. Temperature-salinity relations in the stations from 1 to 9.

main thermocline centered at 20°C was found at depth of 150 m between 9°N and 10°N, and it sloped down to the south at a depth of 200 m south of 5°N. The isothermal water nearly occupied the upper layer above the main thermocline.

T–S relations in Sts. 1~9 are shown in Fig. 2 in order to classify the water masses in this region. It is seen in the figure that the saline water, with salinity exceeding 35.0‰, was found in the upper layer above the depth of 150 m in Sts. 1~4 (the equator to 4°30′N). The salinity of the upper water above the depth of 75 m became low, though the saline water was still found below the depth of 150 m in St. 5 (6°N). The surface water where salinity was less than 34.3‰ was found in Sts. 6~8 (7°30′-10°30′N), and the salinity maximum was obscured at the depth of about 100 m. The other saline water with salinity exceeding 35.0‰ was observed in St. 9 (12°N) at a depth of 150 m.

As stated above, the T–S relation in the surface layer at 164°E from the equator to 12°N can be classified into three groups in connection with the Equatorial Current. The first group represents the South Pacific tropical saline water (Sts. 1~4), which was found as far as 4°30′N. T–S relation in St. 5 was not included in this group because the salinity was low in the layer above the depth of 75 m; the second, the

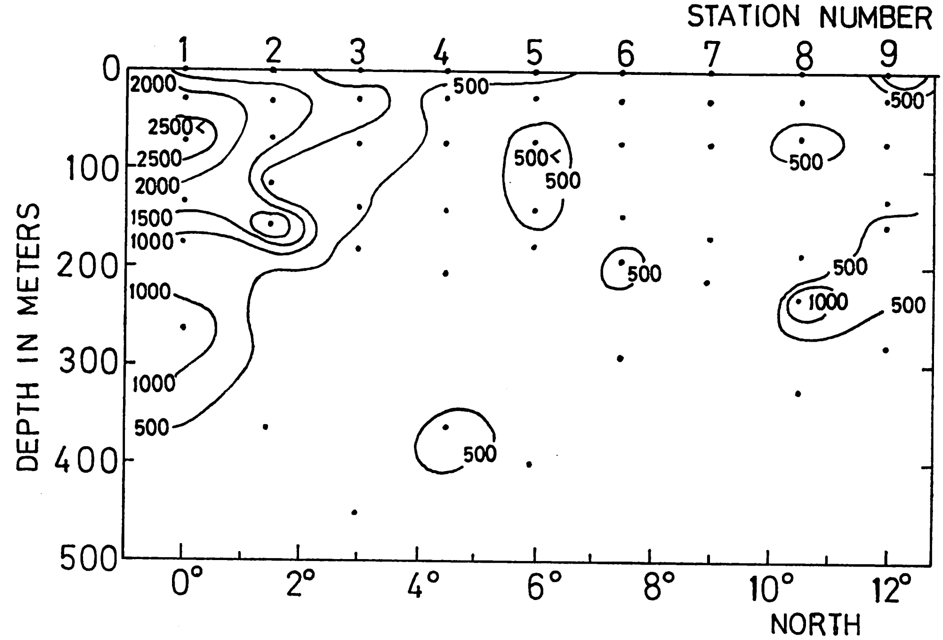

Fig. 3. Vertical section of suspended particles determined by a Coulter Counter ZB with 30 μ aperture tube.

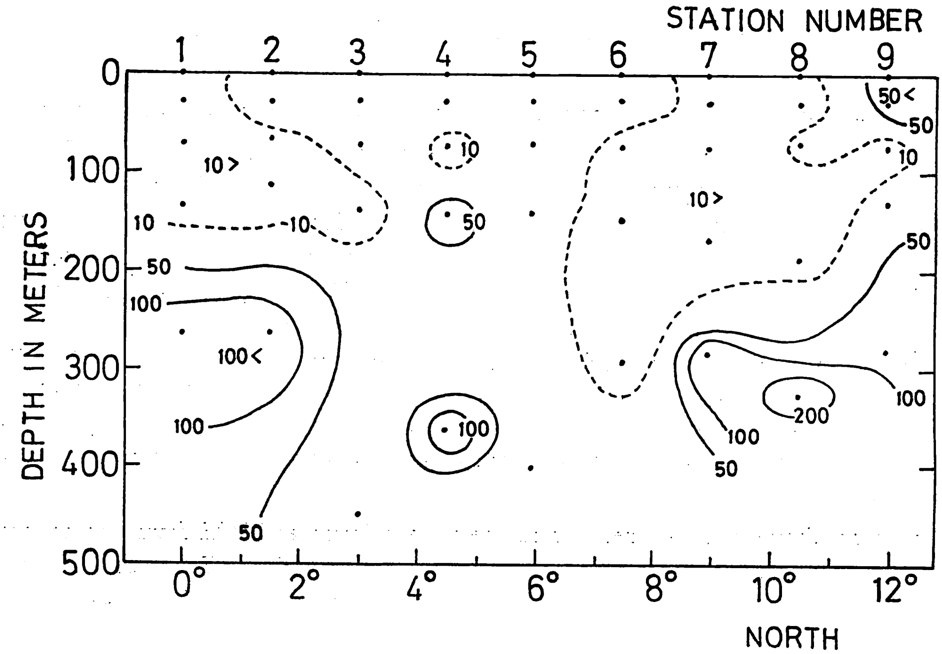

Fig. 4. Vertical section of bacterial population (cells/ml) at 164°E.

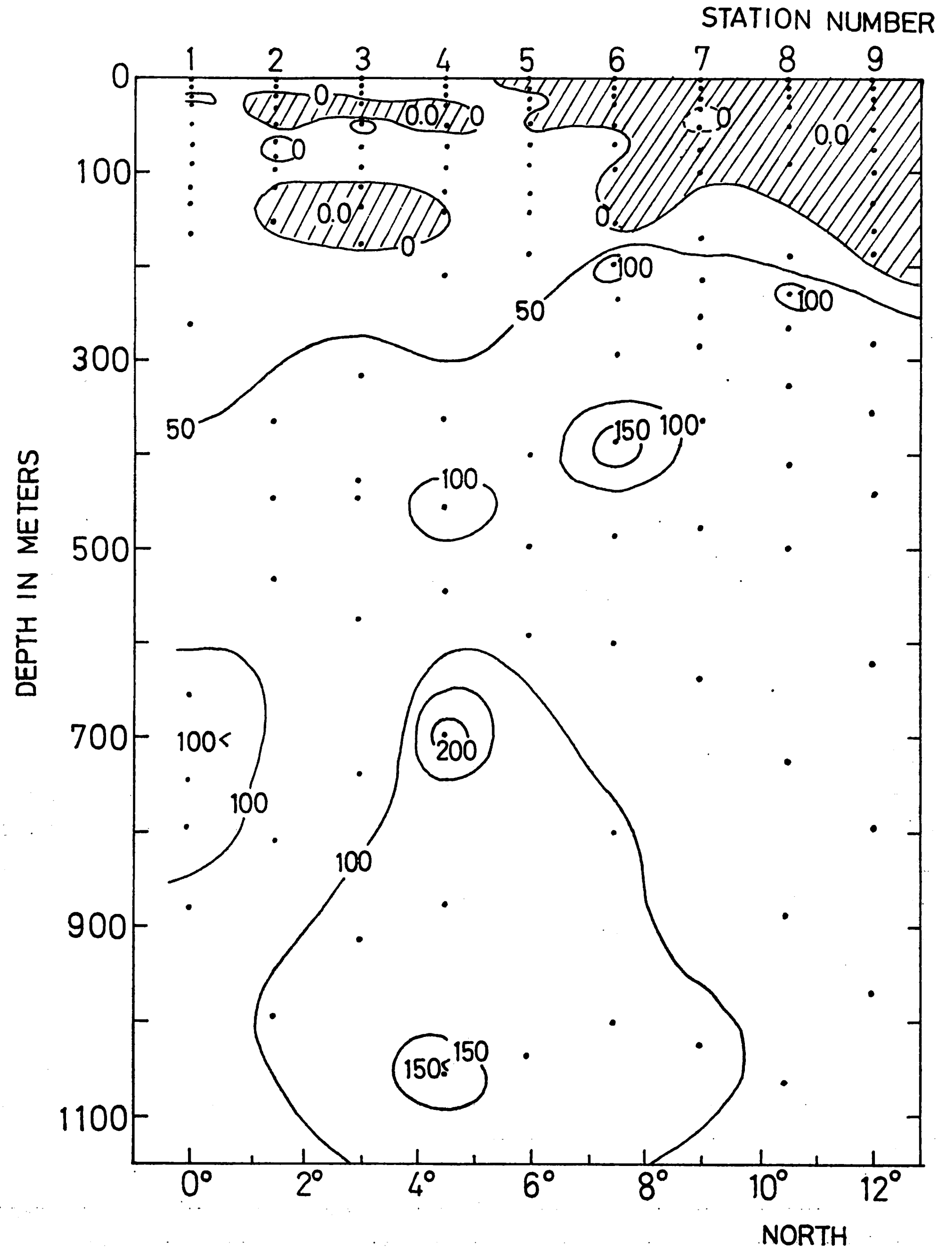

Fig. 5. Vertical section of PO_4-P (ppb) at 164°E.

low salinity water less than3 4.3‰ (Sts. 6~8) which was found in the region from the Equatorial Countercurrent to the southern part of the North Equatorial Current; the third, the North Pacific tropical saline water exceeding salinity of 35.0‰ (St. 9).

2–2. Coulter Counter Analysis

Density of suspended particles including phytoplankton and detritus in the waters was measured by a Coulter Counter ZB with 30μ aperture tube. Bacterial populations in the samples were also counted employing the routine method of plate agar culture using ZoBell 2215E medium (HIRATA, YAMAGUCHI, HIGASHIKAWA, KOBIRATA and WENNO; 1976). Quantity of PO_4–P in all the stations was analyzed by the method described in manuals for oceanograhic observations (JAPANESE METEOLOGICAL SOCIETY; 1970). The results obtained by those methods are presented in Figs. 3∼5.

The number of suspended particles in Sts. 1∼2 was around 2,000 to 4,000 particles per ml. The density was higher than those of the other stations located in both the Equatorial Countercurrent and North Equatorial Current regions. Lower density of the particles, 200 to 800 per ml, was found in Sts. 4∼7. Relatively higher amount of the particles like 1,000 to 2,000 per ml were observed in Sts. 8∼9 in the North Equatorial Current. Therefore, the distribution pattern of the suspended particles in the waters was closely related to three Equatorial Current zones described in previous item.

Similar pattern as metioned above was observed in the case of surface distribution of bacterial organisms as shown in Fig. 4. The populations of the bacteria in the layer above the depth of 200 m in Sts. 1∼2 and 7∼9 were less than 10 cells per ml, while the populations in Sts. 3∼6 were slightly larger than these in both sides. In general, however, bacterial populations around the depth of 300 m were larger at a range of 100∼200 cells per ml, than those of the surface waters.

The PO_4–P content was almost undetected in the surface waters of Sts. 5∼7, while 10∼50 ppb of PO_4–P was observed in the water around Sts. 1∼4. Thesur face waters in Sts. 5∼9 may have originated from the north. The amount of PO_4–P in the South Equatorial Current was slightly higher than that of the North Equatorial Current. From the results of PO_4–P analysis as shown in Fig. 5, some complications caused by the mixing of water masses were found in the Equatorial Countercurrent around St. 4.

2–3. Continuous Records of D. O. Contents

D. O. contents in the surface water were detected by a D. O. meter, Y. S. I. model 57, and recorded continuously during the cruise by a laboratory recorder, Yokogawa Electric Works model 3046. Some examples of the records are presented in Fig. 6a–d.

The continuous record of D. O. jumped immediately or gradiently within a range of 0.05–0.3 ppm in a space of 2–6 miles were registered 35 times in the cruise between Nauru and Guam. The D. O. record of discontinuity may be depended on the structure of the current rip caused by the upwelling. It is interesting to note that the occurence of the discontinuity in the South Equatorial Current zone was much frequent than those in the North Equatorial Current zone.

The types of discontinuity of D. O. content could be classified into three patterns;

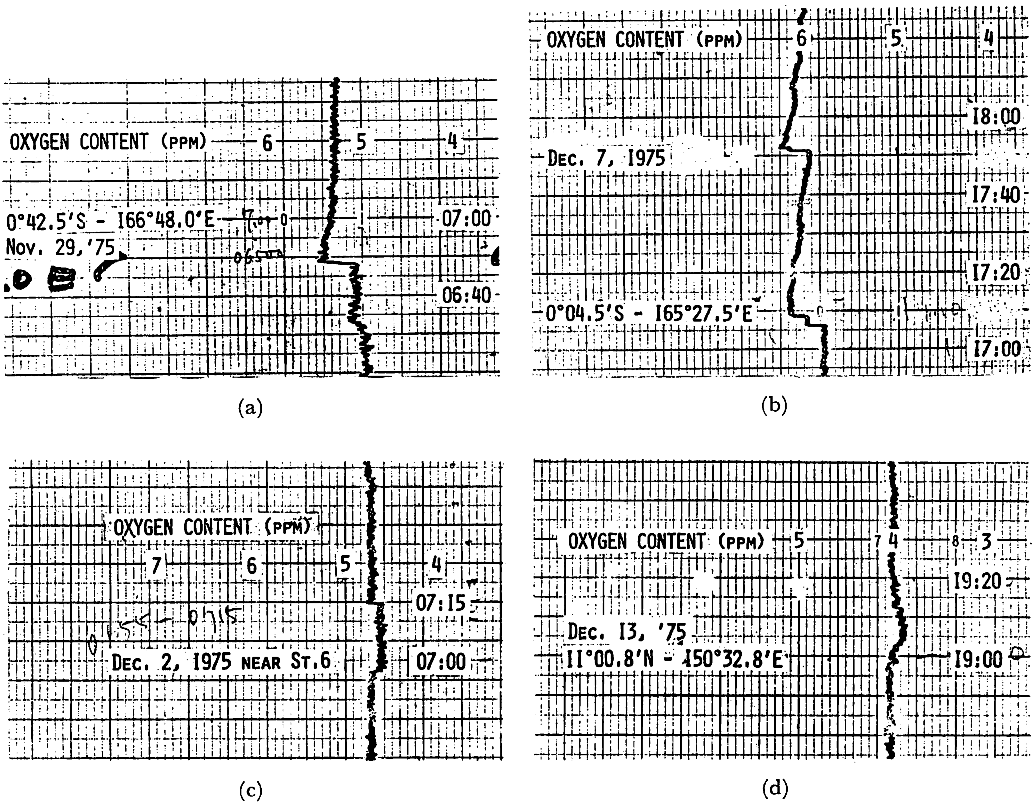

Fig. 6. Examples of continuous D. O. recordings by the cruising.
(a) and (b): jagged curve found at South Equatorial Current,
(c) : zigzag curve recorded frequently at Equatorial Countercurrent and North Equatorial Current, and
(d) : gradient concaved curve detected a few times in the Equatorial Countercurrent zone.

that is, 1) jagged curve as shown in Fig. 6a–b which was mainly recorded in the South Equatorial Current zone, 2) Zigzag curve as indicated in Fig. 6 c which was found frequently in the Equatorial Countercurrent and the North Equatorial Current zones, and 3) gradient concaved curve as shown in Fig. 6 d which was detected a few times in the Equatorial Countercurrent zone.

2–4. Distribution of Zooplankton

The zooplankton samples were collected using a Marutoku plankton net (45 cm in diameter, bolting cloth GG54, 0.33 × 0.33 mm mesh aperture). The net was hauled vertically from an estimated depth of 100 m at each station. The results are presented in Table 1.

An average wet weight of zooplankton biomass in the northern part was 41.5 mg/m^3 at the range of 28.1 ∼ 64.5 mg/m^3. The biomass, 48.0 mg/m^3, in the southern part of section (Sts. 1~4) was larger than those in the northern parts (Sts. 5~9) where was 30.4 mg/m^3 of the biomass on the average.

The main groups of zooplankton were Copepoda, Chaetognatha, Appendicularia, Pteropoda, Amphipoda and Dinoflagellates. The first three groups were especially

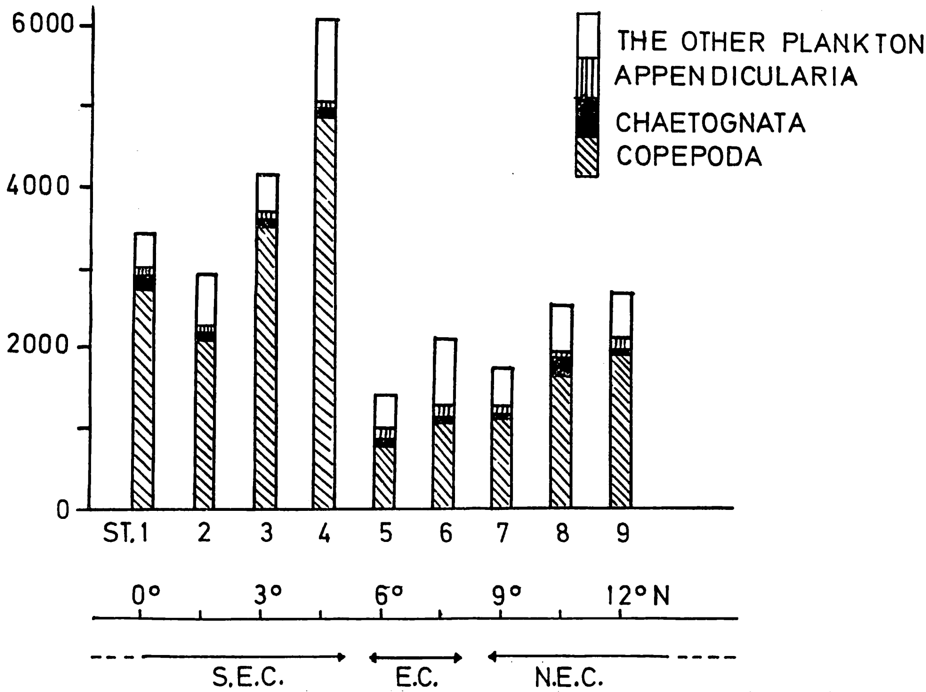

Fig. 7. Distribution of zooplankton inds./haul at 164°E in November, 1975.
SEC: South Equatorial Current; EC: Equatorial Countercurrent; NEC: North Equatorial Current.

Table 1. The collection data of plankton net.

Station No.	Date	Time	Locality Lat.	Long.	Settling volume	Wet weight mg/m^3	Number of animals per haul
1	Nov. 30	0225	0°10'N	163°58'E	4.7 ml	42.7	3400
2	Nov. 30	1125	1°31'N	164°01'E	5.2 ml	39.5	2900
3	Nov. 30	2255	3°00'N	164°00'E	3.2 ml	47.2	4100
4	Dec. 1	0841	4°20'N	16°356'E	7.1 ml	64.5	6050
5	Dec. 1	1920	6°00'N	164°08'E	3.1 ml	28.1	1400
6	Dec. 2	0540	7°37'N	164°19'E	4.2 ml	35.8	2100
7	Dec. 2	1503	8°59'N	164°04'E	3.8 ml	27.5	1750
8	Dec. 3	0030	10°22'N	164°00'E	4.2 ml	30.6	2500
9	Dec. 3	1205	11°59'N	164°01'E	4.8 ml	32.5	2700

Table 2. Number of important plankton animals per haul and its percentages to total animals.

	St. 1	St. 2	St. 3	St. 4	St. 5	St. 6	St. 7	St. 8	St. 9
Dinoflagellates	40 (1.1)	84 (2.8)	130 (3.1)	75 (1.2)	45 (3.2)	68 (3.2)	212 (12.1)	76 (3.0)	96 (3.5)
Chaetognatha	125 (3.6)	86 (2.9)	96 (2.3)	94 (1.5)	85 (6.0)	66 (3.1)	77 (4.4)	210 (8.4)	35 (1.2)
Polychaeta larvae	40 (1.1)	25 (0.8)	64 (1.5)	39 (0.6)	21 (1.5)	18 (0.8)	24 (1.4)	70 (2.8)	16 (0.6)
Cladocera	56 (1.6)	82 (2.8)	68 (1.6)	42 (0.7)	0	0	0	0	0
Copepoda	2700 (79.4)	2100 (72.4)	3450 (84.1)	4850 (80.0)	720 (51.4)	1100 (52.4)	1050 (60.0)	1600 (64.0)	1900 (70.3)
Amphipoda	48 (1.4)	22 (0.7)	16 (0.4)	76 (1.2)	4 (0.3)	16 (0.8)	36 (2.0)	28 (1.1)	8 (0.2)
Pteropoda	45 (1.3)	110 (3.7)	25 (0.6)	64 (1.0)	21 (1.5)	48 (2.3)	25 (1.4)	24 (0.9)	15 (0.5)
Appendicularia	120 (3.5)	80 (2.7)	75 (1.8)	60 (1.0)	140 (10.0)	120 (5.7)	75 (4.3)	45 (1.8)	160 (5.9)
Thaliacea	11 (0.3)	8 (0.2)	16 (0.4)	12 (0.2)	6 (0.4)	4 (0.2)	0	7 (0.3)	6 (0.2)
The other planktons	215 (6.3)	303 (10.4)	160 (3.9)	738 (12.2)	358 (25.5)	660 (31.4)	251 (14.3)	440 (17.6)	464 (17.2)
Total	3400 (100.0)	2900 (100.0)	4100 (100.0)	6050 (100.0)	1400 (100.0)	2100 (100.0)	1750 (100.0)	2500 (100.0)	2700 (100.0)

important species because they control the plankton volume at each station.

The individual number and percentage composition of macroplankton are shown in Table 2 and Fig. 7. Based on the Table, there was a distinct difference in plankton populations between the southern part (Sts. 1～4) and the northern part (Sts. 5～9). In the southern area, the total number of aminals varied from 2,900 to 6,050 individuals per haul with an average of 4,100 individuals per haul. The mean value of plankton animals was 4,040 individuals per haul in the northern part, and this was only half of the population in the southern sea investigated. The difference between those two sea areas was more distinctly shown by the distribution of Copepoda. The average number of Copepoda was 3,275 animals per haul in the northern area. The number in the southern sea was three times higher than that of the northern area. Also, in the southern sea, there were many large sized Copepoda such as *Eucalanus elongatus, Eucalanus attennuatus, Euchaeta wolfendeni,* which were very few in the northern area. The Cladoceran (*Evadne* sp.) appeared only in the southern part.

As stated earlier in item 2–1, the Equatorial Current in the sections could be divided into three parts as follows: that is, South Equatorial Current at Sts. 1～4, Equatorial Countercurrent at Sts. 5～6 and North Equatorial Current at Sts. 7～9. The variations in planktological properties corresponded to those of the oceanographic conditions. The populations of zooplankton were small in the North Equatorial Current and the Equatorial Countercurrent, while the large populations were found in the South Equatorial Current.

3. Discussion

NAGAYA (1975) studied the zooplankton biomass in the Equatorial Current region at 140°～151°E in summer of 1955 and 1956. According to the report, displacement volume of zooplankton in the North Equatorial Countercurrent (10°～20°N) was large, being 0.085 ml/m^3 on average, as well as in the Equatorial Countercurrent (5°～10°N). KAWARADA, KITOU, FURUHASHI and SANO (1967) aslo have reported that the biomass of the equator to 12°N at 137°E was 18 mg/m^3 on the average at the range of 4 to 44 mg/m^3. The value reported by NAGAYA (1957) was about 4 times as large as the results obtained by KAWARADA, KITOU, FURUHASHI and SANO (1967). The biomass of zooplankton observed in the present survey was similar to the former report (NAGAYA; 1957). Perhaps the population of zooplankton in the 151°～164°E was larger than that in the 137°E sections at the Equatorial Current region.

High correlation between the density of suspended particles presented in Fig. 3 and the biomass of zooplankton as shown in Fig. 7 was found in the present survey. That is, the density of both the particles and the zooplankton in the South Equatorial Current were higher than those in the North Equatorial Current. It may be considered from these results that the suspended particles probabely correspond to the detritus mentioned by NISHIZAWA (1966 and 1969). It is also interested to note that the distributions of both the particles and the zooplankton were related to the three types of the Current such as the South Equatorial Current, the Equatorial Countercurrent the and the North Equatorial Current.

It is well known that high productivity in the Equatorial Current region is caused by the upwelling of the water masses (NAKAMURA and YAMANAKA, 1959, YAMANAKA, 1969 and 1975). However, the mechanism of upwelling is still not well understood. The discontinuity of D. O. records within a space of 2 to 6 miles at the range of 0.05 to 0.3 ppm were found frequently by the continuos record of D. O. content on board. This method may be served to detect the small current rips which was probably due to the upwelling of water masses. The continuous recording of D. O. content have been done by MASUDA (1974), but it was only used to investigate the red-tide in the Mikawa Bay. The results obtained in this study could be applied to micro-oceano graphy and fishery biology in the Equatorial Current region.

4. Acknowledgements

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